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ABSTRACT

This activity is designed for secondary school students. The process of constructing a model solar building includes consideration of many fundamental scientific principles, such as the nature of heat, light, electricity, and energy conversion technology. When the model solar building is completed, there are numerous possibilities for the use of the model for studies of the principles of energy conversion. Included are a description of needed materials and equipment, construction tips, diagrams to assist in the construction procedures, suggested uses of the model, and selected references. (RH)

CONSTRUCTION OF A MODEL SOLAR BUILDING

A Learning Experience for
Coastal and Oceanic
Awareness Studies

Produced by

MARINE ENVIRONMENT CURRICULUM STUDY
MARINE ADVISORY SERVICE
UNIVERSITY OF DELAWARE

and

POPULATION-ENVIRONMENT CURRICULUM STUDY
COLLEGE OF EDUCATION
UNIVERSITY OF DELAWARE

as part of a

PLAN FOR ENVIRONMENTAL EDUCATION

Fall 1974

Please send evaluations

of learning experiences

to

Dr. Robert W. Stegner, Director

COAST Project

310 Willard Hall Education Building

University of Delaware

Newark, Delaware 19711

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DEPARTMENT OF PUBLIC INSTRUCTION

DEL MOD SYSTEM

DUPONT EDUCATIONAL AID COMMITTEE

TITLE: CONSTRUCTION OF A MODEL SOLAR BUILDING

*CONCEPT: VI.B.2.

VI. By planning within the natural system, a life of acceptable quality can be provided for all people.

B. Social and technological programs can improve the use of resources, prevent environmental degradation and protect human rights.

2. TECHNOLOGY COULD BE MORE FULLY EMPLOYED FOR THE BENEFIT OF MAN AND THE ENVIRONMENT.

**MARINE CONCEPT: 4.3

4. Man is part of the marine ecosystem.

4.3 EXISTING TECHNOLOGY IS CAPABLE OF MAINTAINING THE HEALTH AND USEFULNESS OF MARINE ECOSYSTEMS.

SUBJECT: Science

GRADE LEVEL: 9-12

PERIODS: Various

AUTHOR: Cross

TEACHER BACKGROUND

See learning experience I.B.1.a.(1)(Mar. 4.3) "Solar Energy Conversion Background Information, available from Population-Environment Curriculum Study, 310 Willard Hall, University of Delaware, Newark, DE 19711.

The process of constructing a model solar building will include consideration of many fundamental science principles, such as the nature of heat, light, electricity and energy conversion technology. When the model solar building is completed, there are numerous possibilities for the use of the model for studies of the principles of energy conversion.

This model can be inspected in the office of the Population-Environment Curriculum Study, 310 Willard Hall, University of Delaware, Newark, DE 19711.

* From A Conceptual Scheme for Population-Environment Studies, 1973. Cost, $2.50.

** From Marine Environment Proposed Conceptual Scheme, 1973. No charge.

Both conceptual schemes are available from Robert W. Stegner, Population-Environment Curriculum Study, 310 Willard Hall, University of Delaware, Newark, DE 19711.

EQUIPMENT AND SUPPLIES

1. Solar Drive Motor, Model EP-50, made by International Rectifier Corp., distributed by Edmund Scientific Company, 300 Edscorp Bldg., Barrington, NJ 08007, Catalog No. 40872, $5.20* (A staff member at the Institute of Energy Conversion at the University of Delaware has suggested that a better motor, with less starting torque and higher efficiency, could be obtained from Micro-Mo Electronics, Corp., 3691 Lee Road, Cleveland, OH 44120.)

2. Solar Batteries (photovoltaic cells) - Model S4M silicon solar cells made by International Rectifier Corp., distributed by D&M Radio and Electronics Co., 215 W. 4th St., Wilmington, De. 19801. $3.95.* Four are sufficient.

3. Diode - Any general purpose rectifier diode will suffice. Should be available from any electronics supply house such as Radio Shack, D&M Electronics, etc. Costs less than one dollar.

4. DC Miniature Water Pump - Pumps 7-1/2 gallons per hour to a height of 24 inches. Available from Edmund Scientific Co., 300 Edscorp Bldg., Barrington, N.J. 08007, Catalog No. 50345, $2.25.*

5. Rechargeable Battery - 2 D-size Nickel-cadmium batteries are used to operate the water pump and motor. The pair cost $4.50* at Lafayette Radio, Kirkwood Highway, Wilmington, De.

6. Meters - Depending upon the activities that you want to do with your class, you may want a DC multimeter or ammeter and voltmeter with the range 0-250 ma and 0-3 volts, respectively, or a galvanometer of similar range. Any educational supply house should be able to supply these.

7. Miscellaneous

   (a) Connecting wire - 10 feet
   (b) Soldering iron and solder
   (c) Flexible copper tubing - 5 feet, 3/8" O.D.
   (d) Tygon plastic tubing to fit over the copper tubing, 3 ft.
   (e) Copper plate - 6-1/2" x 18"
   (f) Small wood screws - 3/8" flathead
   (g) Plexiglas, 1/8" thick
   (h) 1/4" plywood, one side good, 4 ft. x 4 ft. sheet
   (i) Sponge rubber sheets, 1" thick, approx. 10 sq. ft.
   (j) One gallon rectangular gas can
   (k) Aluminum foil, 2" x 18-1/2"
   (l) Flat black paint
   (m) Wood block, 9" x 3" x 1/4"
   (n) #9 rubber stopper
   (o) 3 switches
   (p) Small light and appropriate fixture

   The above items can be obtained at any hardware store. The most expensive items will be the copper tubing ($.50 per foot) and the plywood. The plexiglas can be purchased in 5" strips which are leftover scraps from the cutting of larger pieces.

*These prices may have changed since the model was first designed and built.

CONSTRUCTION OF A MODEL SOLAR BUILDING

The miniature building described below was modeled partially after the University of Delaware's solar house, Solar One, and partially after the solar-heated house designed by Dr. Harry E. Thomason. (Plans for Dr. Thomason's house are available from Edmund Scientific Company.) The model was not intended to resemble the above houses in appearance. The appearance of the model, except for the slope of the roof section, was not of prime concern in the construction, since the building is primarily a box to house the solar electrical and solar heating systems.

The Frame

The building was constructed from 1/4-inch plywood and 1/8-inch plexiglas. The dimensions of the various pieces are provided in Figure 1, pp. 8,9,10, 11. The pieces were fastened together with 3/8-inch flathead wood screws. It is a good idea to pre-drill the holes before putting in the screws to avoid splitting the plywood. Care must be taken to avoid cracking the plexiglas although it can be cut with woodworking tools. The basement compartment and the upper part of the building were constructed separately to allow access to the basement for installation of the water storage tank. The roof piece was not attached by screws but is simply placed on top and held by the interior insulation. This makes it easy to install the electrical components and provides access for later demonstrations and experiments. The windows are covered by plexiglas which can be glued in place or attached by 1/4-inch screws. The entire interior of the house is lined with 1-inch foam rubber insulation.

The Heating System

The heating system of the model is similar to that used in the Thomason house (See Figure 2, p. 12.) The five-foot copper tube, 3/8-inch outer diameter, was carefully bent into the 5-1/2-inch loops shown. The copper tube was then soldered to the copper heat collection plate, 6-1/2 inches x 18 inches. Care must be taken that the coils are flat against the plate so that good contact is made to achieve as much heat transfer as possible. Both the collector plate and the copper tubing are painted flat black. The copper tube extends beyond the plate so that the plastic tubing can be attached. Both plastic tubes are extended to the water storage tank in the basement. The water storage tank is a rectangular, gallon gas can, 6 inches x 9 inches x 4 inches.

Since hot water will rise to the top of the storage tank, it is necessary to locate the water pump near the bottom of the tank so that the cool water is being pumped to the coils in the roof for heating. The water pump is inserted in the can and the top of the pump extends out of the opening. A rubber stopper is bored out so that the top of the pump fits into it. The stopper is then inserted into the opening of the can. This will protect the electrical parts of the pump from the water. A more suitable arrangement would be to have the pump located outside the tank with a tube leading to the bottom of the tank, if a suitable pump can be located. The water storage tank is well insulated except for the top which is exposed to the interior of the house to allow for heat exchange. Thomason uses a fan and ductwork to move hot air from the storage tank up to the house.

An alternative to the above heating system would be the type described by D.S. Halacy in the book Solar Science Projects (Scholastic Book Services, 1971). Halacy describes a hot water system that makes use of thermosiphoning. The advantage of his system is that no pump is necessary to circulate the water since the coils are located below the storage tank and the hot water will rise as the cold water settles down to the coils. However, cold water must still be pumped up into the tank to replace the hot water that overflows the top of the tank.

The Electrical System

The electrical system of the model is similar to that of Solar One. The appliances of the house, water pump, light bulb and motor, are operated by direct current from two D -size Ni-Cad batteries in series. The batteries are recharged by 5 silicon solar cells in series. A diode is placed in the circuit between the solar cells and the batteries to prevent current from flowing from the batteries to the solar cells while allowing current to flow from the cells to the batteries. The diode is the Motorola HEP 134, but any general purpose diode should suffice. The diode is rated at 60 volts and 50 milliamps of current forward. If confusion arises as to which lead of the diode is positive and which is negative, the diode may be temporarily placed in a series circuit and an ammeter used to determine in which direction current is flowing.

The solar cells are silicon cells that produce approximately 0.55 volts and 46 milliamps at short circuit. The I-V characteristic curve for one of the cells is shown in Figure #3, p.13. It was made using the full sunlight simulator at the Institute of Energy Conversion, University of Delaware. This particular cell produces maximum power at 39 ma and 0.43 volts.

Power= Current x Voltage = 0.017 watts

The wires of the cell were cut as short as possible to avoid power losses due to resistance. To connect the cells in series, the positive lead of one cell was soldered to the negative lead of another, and so on. The Ni-Cad batteries each produce about 1.25 volts and have a carrying capacity of about 1.2 amp hours. The batteries can be fully charged from complete discharge by 80 ma of current at 2.5 volts for 16 hours. The five cells in series will produce about 45 ma at 2.8 volts. Therefore, it will take about 32 hours of bright sunlight to completely charge the two batteries using the array of solar cells indicated.

This is the result of a compromise between desirability and cost. To charge the two batteries we need at least 2.5 volts from the solar array to buck the 2.5 volts that would result from even a highly discharged battery system. Yet, the output of the solar cells cannot be much more than 2.5 volts, since this may damage the batteries. Thus, the charging voltage is set at 2.8 volts from 5 cells.

We could use 10 cells having 5 sets of 2 cells in parallel. This would give about 2.8 volts at 90 ma in bright sunlight, but it would require about 40 dollars for 10 solar cells rather than 20 dollars for 5 cells. The advantage of the CdS/Cu_2S cell used by the Institute of Energy Conversion is that they can be produced at a lower cost than the silicon wafers and that they can be cut into different sizes to adjust the circuit and voltage produced. However, the CdS/Cu_2S cells are not yet commercially available. (See Figure 4, p.14 for a diagram of the electrical circuit.) The batteries, diode, and motor, were mounted on a 9 inch x 3 inch x 1/4 inch board. A solar motor is in a separate circuit to demonstrate that the solar cell array will operate a motor directly, without going through the batteries. Again, the batteries are meant to store electricity produced during the day, when demand is down, for nighttime use when demand is high. The soldered connections were left exposed so that meters could be easily connected by means of alligator clamps to various parts of the circuit for monitoring the system and for educational demonstrations.

A 100-watt bulb located about one foot from the solar cells is equivalent to bright sunlight. If the lamp is to be placed this close to the cells, however, care must be taken to avoid melting the plastic casings of the cells. A fan would prevent excessive heat buildup. Flourescent lighting would be desirable since it does not give off so much heat.

Uses of the Model

The model house could be used for a variety of educational activities from junior high science through 12th grade physics. Some suggestions are listed below.

1. Place the house outside in the bright sunlight on a cold day. Circulate the water through the coils using the pump. Compare the interior temperature of the building with the exterior temperature. (Note: It may be desirable to use a D.C. power supply to operate the pump since prolonged use of the batteries will drain them faster than they can be recharged. Remember, this particular model is not electrically self-sufficient due to the high cost of solar cells.)

2. Have students draw a circuit diagram of the electrical system of the building.

3. Students can use an ammeter to measure the current coming from the solar cells and determine the drain that the batteries could stand from the load and still be recharged by the current from the solar cells for a typical day.

4. Students could suggest ways to improve the performance of the solar heating and solar electrical systems.

Appreciation and Acknowledgement

Dr. Robert Stegner, for advice and suggestions as to what direction this project should take.

Dr. Hank Hadley, for much needed and appreciated advice concerning the electrical system of the house.

REFERENCES

By providing background information about solar energy conversion and giving ideas for designing and building the model, the following resource materials proved especially helpful.

1. Böer, K.W. 1973. A description of the energy conversion system of the University of Delaware solar house. Institute of Energy Conversion, University of Delaware. July 20.

2. Böer, K.W. 1973. The solar house and its portent. Chemtech. July.

3. Böer, K.W.; Maria Telkes; John Trela. 1973. Solar One - A systems approach to solar energy conversion. Naturalist.

4. Farber, Erich A. 1973. Solar energy--its conversion and utilization. Solar Energy (Journal) 14, 243-252. Pergamon Press, Elmsford, N.Y.

5. Gordon and Breach. 1971. Solar Cells. Gordon & Breach Science Publishers, Ltd. London, England.

6. Halacy, D.S. Jr. 1971. Solar Science Projects. Scholastic Book Services, New York.

7. Institute of Energy Conversion. Solar One-- The First House to Convert Sunlight into Electricity and Heat. University of Delaware, Newark, Delaware.

8. Ralph, E.L. 1973. A commercial solar cell array design. Solar Energy (Journal) . Pergamon Press, Elmsford, N.Y.

9. -----1974. Solar energy. Mosaic. National Science Foundation, Washington, D.C. Spring: 5(2).

10. Sutton, George W. 1966. Direct Energy Conversion. McGraw-Hill, Inc., New York.

Figure 1(a): Upper Portion- Composite View

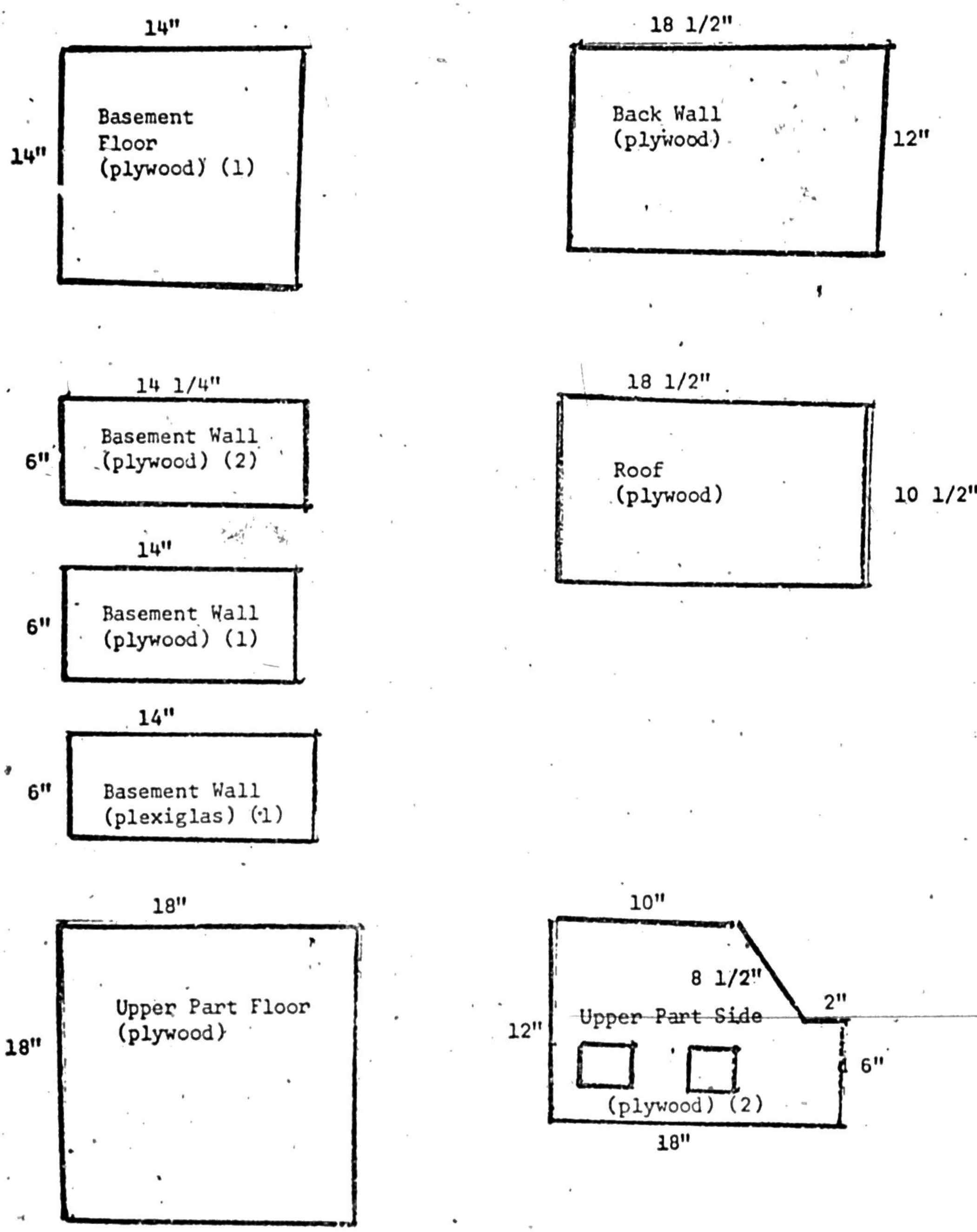
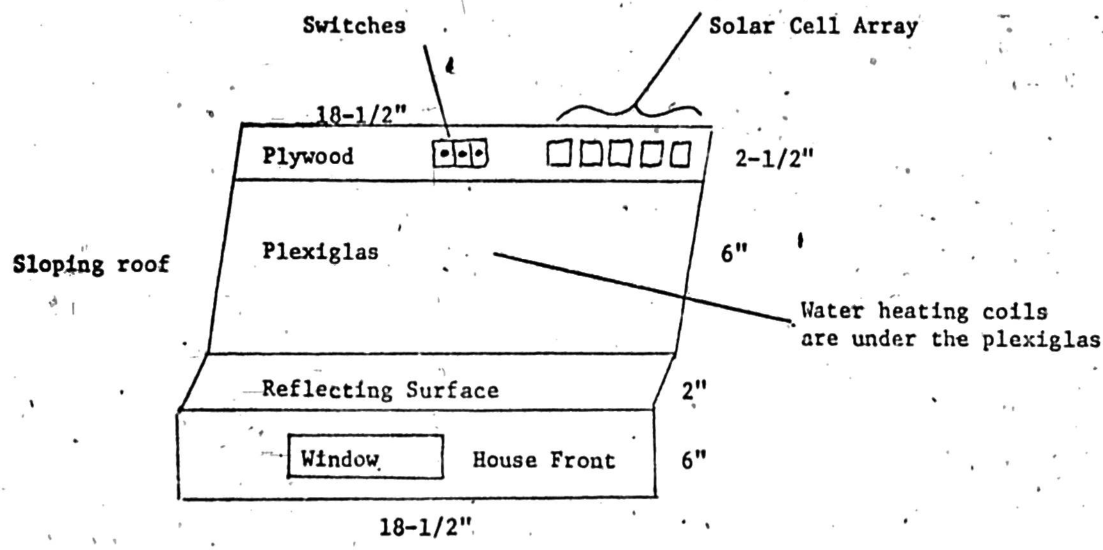
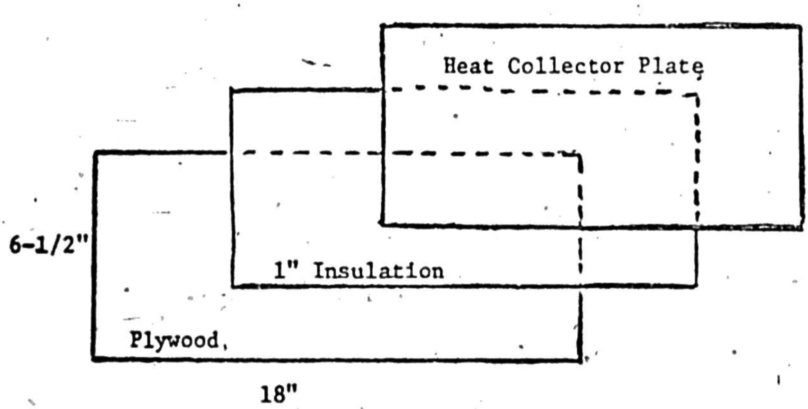


Figure 1(b)



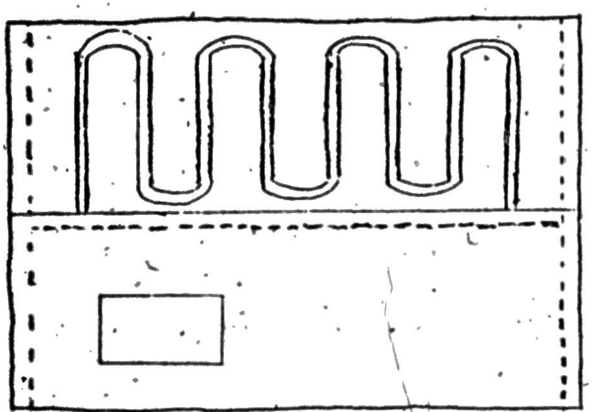
Front view: The reflecting surface refers to an aluminum foil covering over the 2" plywood panel. Its purpose is to increase the amount of light reaching the heating panel and solar cells.



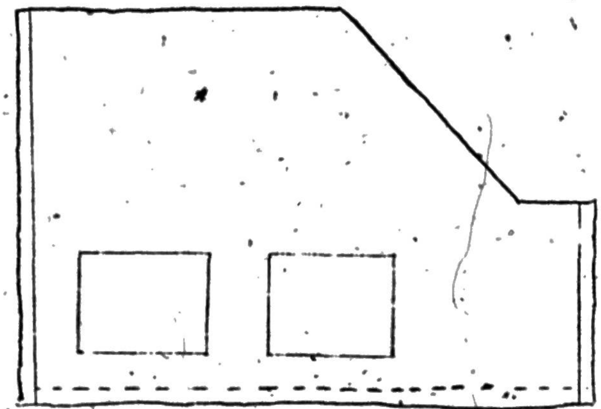
Heat Collection Apparatus:
This unit will be supported beneath the plexiglas on the sloping roof by wood braces 1-1/2 inches below the slope.

Upper Portion:
Composite View

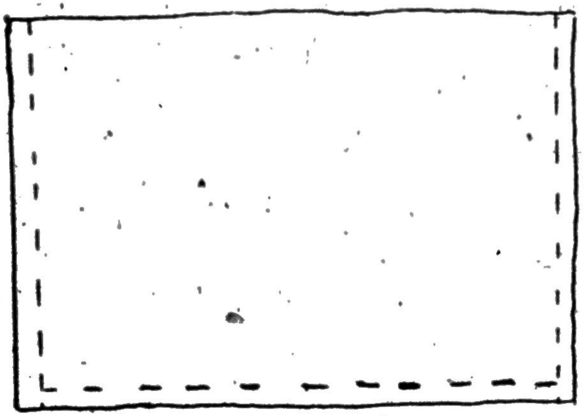
Figure 1(c)



Front

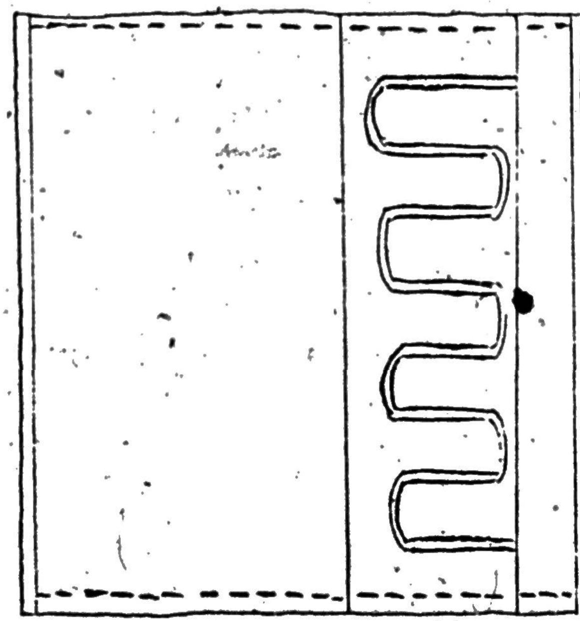


Side



Rear

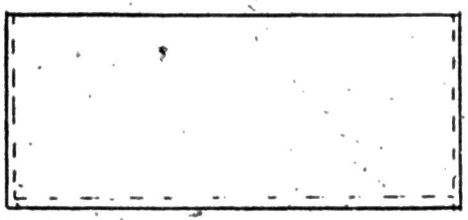
Top



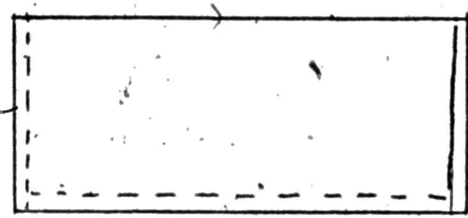
VI.B.2.(Mar. 4.3)
p. 9

Basement: Composite View

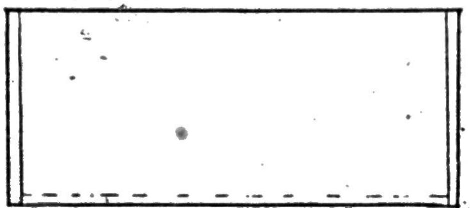
Figure 1(d)



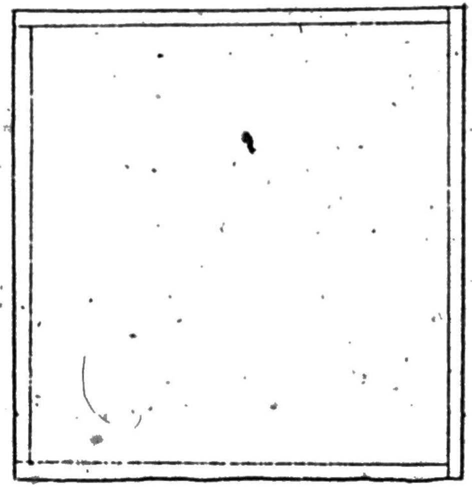
Front



Side



Back



Top

VI.B.2. (Mar. 4.5) p. 10

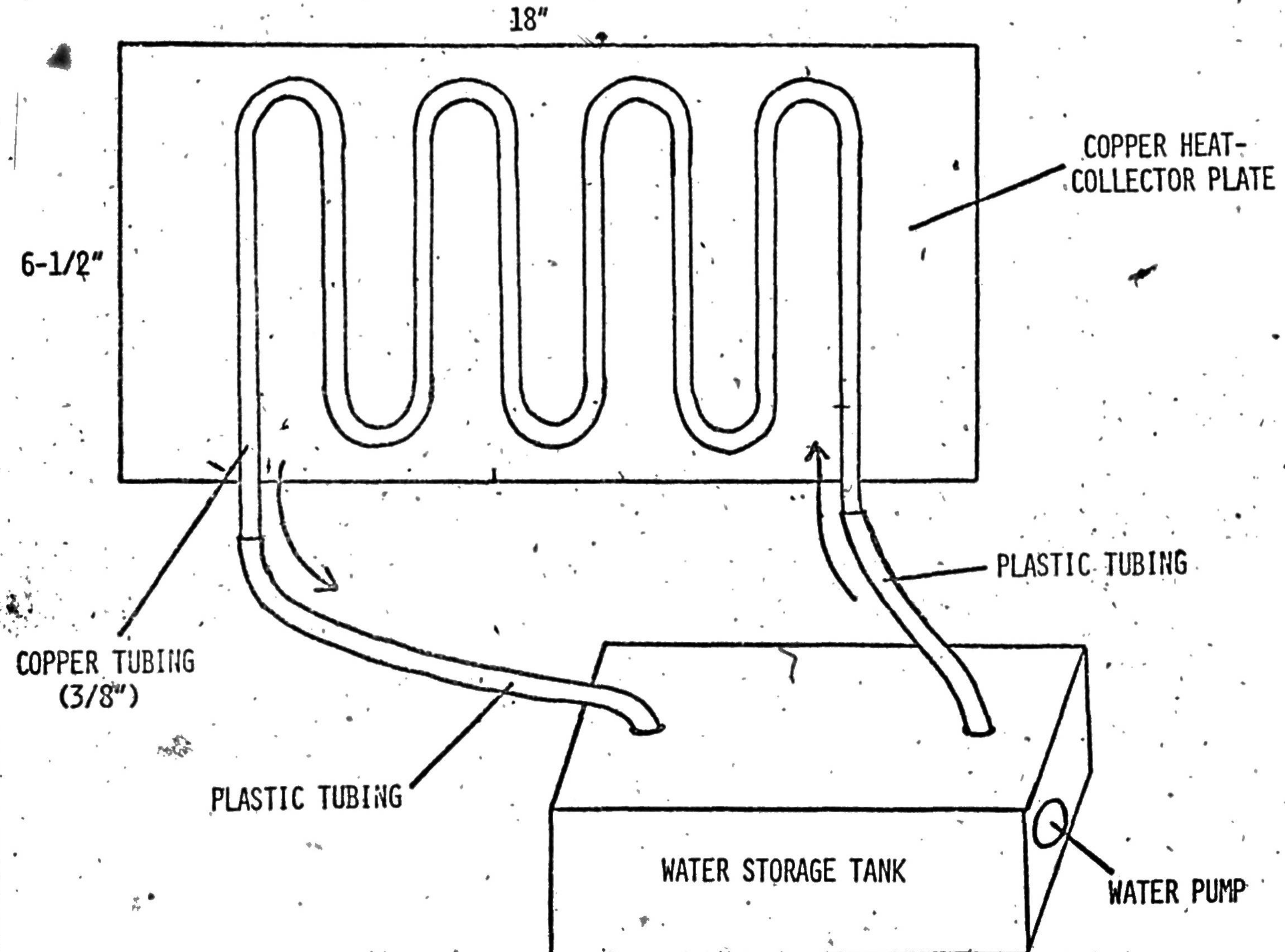


FIGURE 2: HEATING SYSTEM DIAGRAM

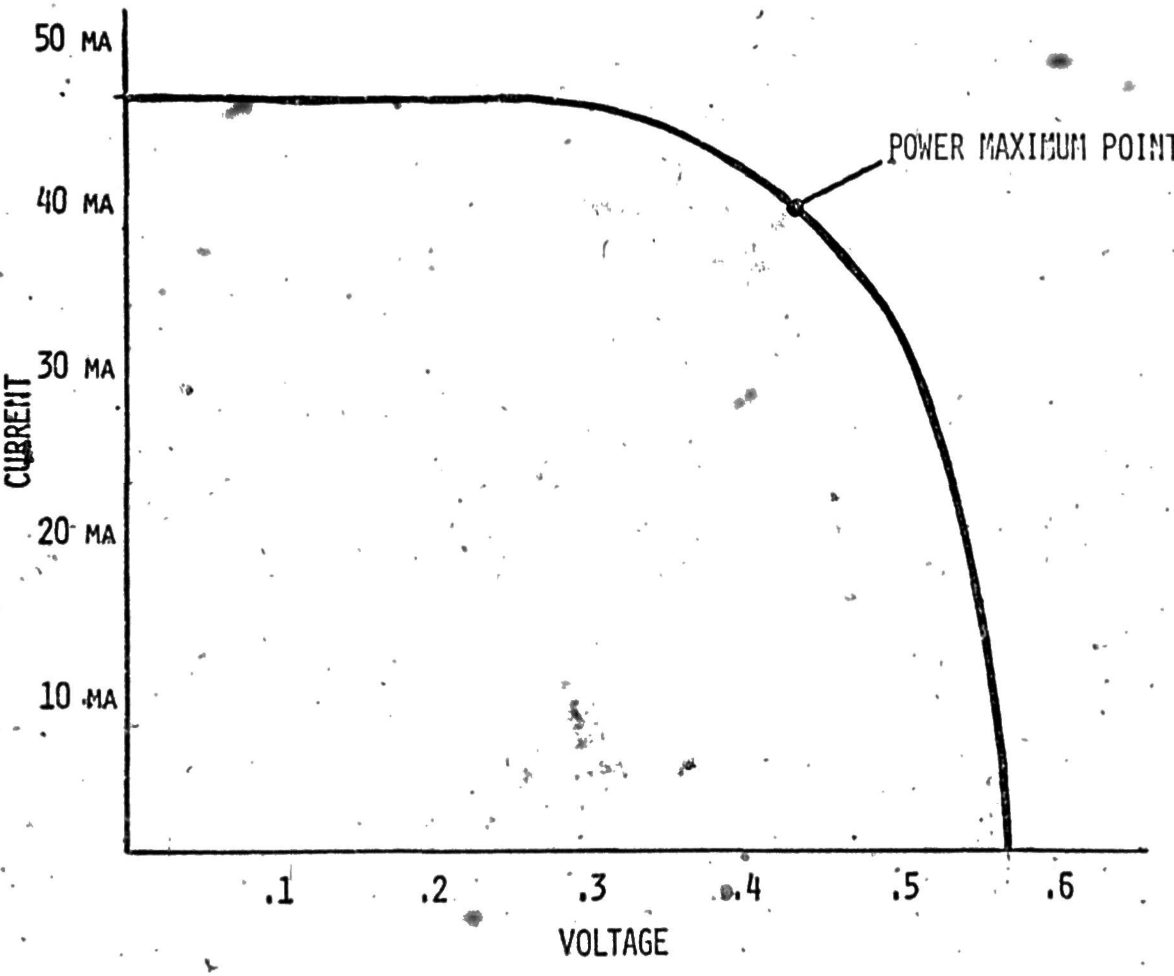


FIGURE 3

I-V CHARACTERISTICS FOR A TYPICAL
SOLAR CELL (1 X 2 cm SILICON) UNDER BRIGHT SUNLIGHT

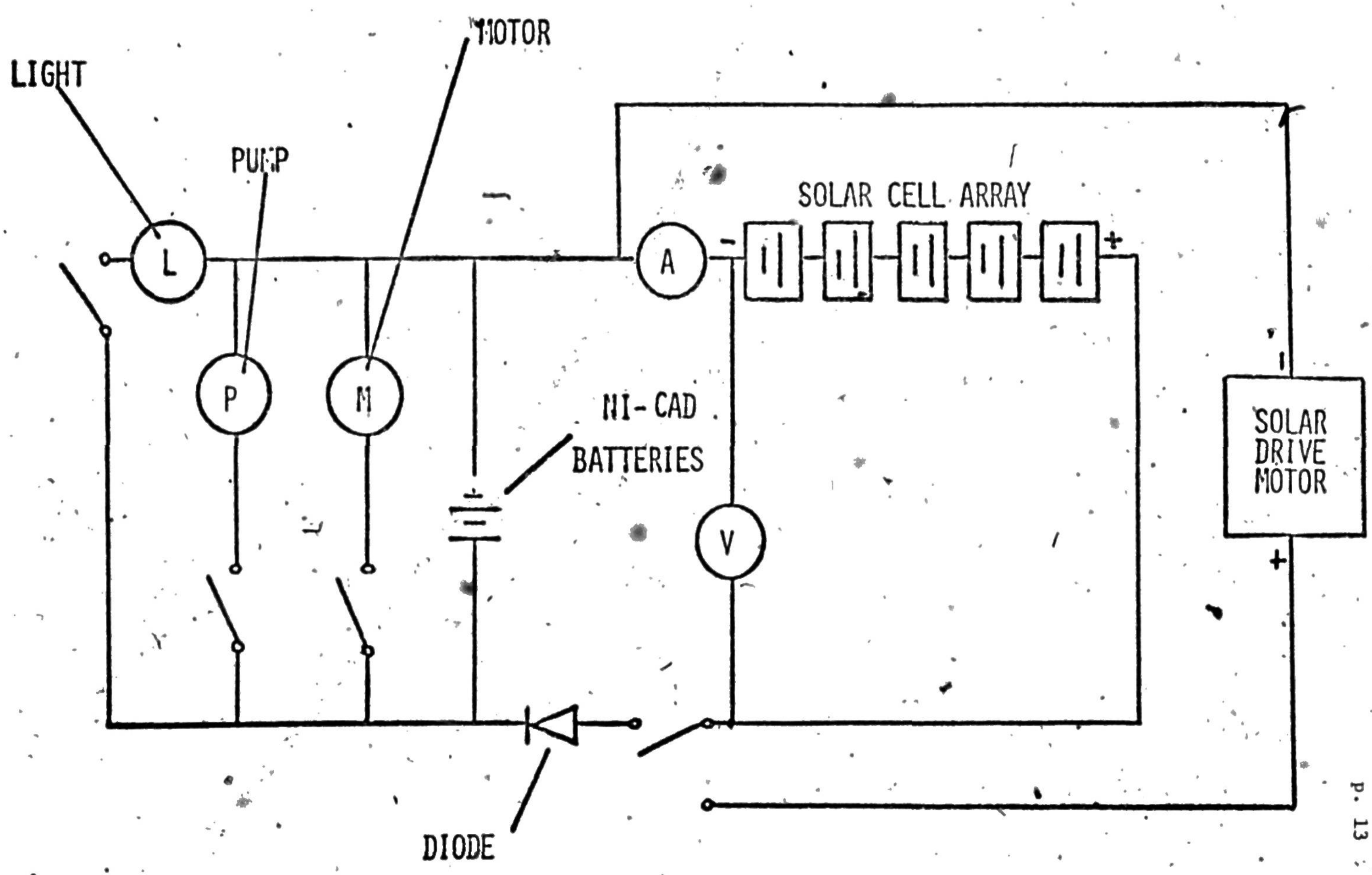


FIGURE 4: DIAGRAM OF THE ELECTRICAL SYSTEM